27 January 1961, Volume 133, Number 3448 SCIENCE

The Moral Un-Neutrality of Science

The scientist's special responsibilities are examined in an address given at the 1960 AAAS annual meeting.

Introduction by Warren Weaver

We live, as our grandparents did not, in a highly interconnected world.

The political, geographic, and communicative interconnections are made almost painfully obvious every morning when we listen to the radio news. Laos and Leopoldville, Moscow and Manila, Johannesburg and Jakarta are with us at the breakfast table, as immediate and pressing as the signal for the school bus. And across our evening sky there swims a communication satellite, symbol of the fact that both voice and vision can now extend over our whole planet.

Even more significant, however, are the new interconnections which are developing within the world of the mind. There used to be comforting compartments within any one of which a person could live and work and think, reasonably protected against—almost insulated from—the rest of the world of ideas. But, largely in the last half century, this has ceased to be so.

This vanishing of intellectual boundaries has, in particular, occurred inside science. About 1920 the line between chemistry and physics began to disappear. At superficial levels of application—the cookery level of chemistry and the hardware level of physics—one can still tell the two subjects apart. But fundamentally they have now become one.

Even more spectacular and surprising is the fact that biology is now in the process of becoming completely absorbed into and merged with all the rest of science. The modern molecular biologist is a chemist, a physicist, a mathematician, a submicroscopic cytologist—in short, a *scientist*. The origin of the elements, the origin of life, and the origin of species—these have now become interrelated parts of one grand problem.

In the good old days when chemistry still smelled like chemistry and biology stayed put inside the biology building, when physics was the harmless preoccupation of a few professors, when mathematics consisted of one useful part called arithmetic and a second part that any sensible person recognized as incomprehensible—in those good old days our grandfathers really did not have cause for much general worry or concern about science. One was relatively free to take it or leave it alone. Electric motors and lights and automobiles and better medicines and some improved seeds were becoming available, and that all seemed a good idea. A very few persons were confused and troubled about what they supposed science had to say about religion. The poets occasionally sneered at science, but this was pretty well canceled out by the fact that scientists kept on reading poetry.

Although there were a few prophets, the vast proportion of men knew little or nothing about science and did not—at least consciously or obviously—suffer from that fact.

This has now all been changed. We now realize that science cannot be disregarded. We now know that science is intertwined not only with political and economic problems but with all the concerns of the humanists and artists. We now know that the mind and spirit of man approaches reality from many directions, appreciates order and beauty in many manifestations, and by joining all forces brings creative imagination and revealing insight to bear on all aspects of nature, of life, and of living. We now know that the poet and the physicist, the musician and the mathematician, the artist and the statesman, and the philosopher and the astronomer attack their problems with essentially the same intellectual and spiritual resources.

But although everyone realizes that our geographical world has become one and that the political world is intimately interrelated, most men are more tardy, or more reluctant, to recognize and profit by the emerging unity of the world of the mind.

Sir Charles Percy Snow has become recognized as the most authoritative and most moving spokesman for the view that we must rejoin the pieces of our fractured culture, must restore the unity of the world of the mind. Himself a distinguished practitioner in science and in the creative arts, he has made a responsible and reasoned plea that our culture be a unified one.

He speaks to us on a theme which

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deals with one of the most interesting and difficult aspects of the interrelatedness of science with all the rest of life, an interrelationship which many disregard, which most debate, and which some deny—the moral unneutrality of science.

Address by Charles P. Snow

Scientists are the most important occupational group in the world today. At this moment, what they do is of passionate concern to the whole of human society. At this moment, the scientists have little influence on the world effect of what they do. Yet, potentially, they can have great influence. The rest of the world is frightened both of what they do—that is, of the intellectual discoveries of science—and of its effect. The rest of the world, transferring its fears, is frightened of the scientists themselves and tends to think of them as radically different from other men.

As an ex-scientist, if I may call myself so, I know that is nonsense. I have even tried to express in fiction some kinds of scientific temperament and scientific experience. I know well enough that scientists are very much like other men. After all, we are all human, even if some of us don't give that appearance. I think I would be prepared to risk a generalization. The scientists I have known (and because of my official life I have known as many as anyone in the world) have been in certain respects just perceptibly more morally admirable than most other groups of intelligent men.

That is a sweeping statement, and I mean it only in a statistical sense. But I think there is just a little in it. The moral qualities I admire in scientists are quite simple ones, but I am very suspicious of attempts to oversubtilize moral qualities. It is nearly always a sign, not of true sophistication, but of a specific kind of triviality. So I admire in scientists very simple virtues—like courage, truth-telling, kindness—in which, judged by the low standards which the rest of us manage to achieve, the scientists are not deficient. I think on the whole the scientists make slightly better husbands and fathers than most of us, and I admire them for it. I don't know the figures, and I should be curious to have them sorted out, but I am prepared to bet that the proportion of divorces among scientists is slightly but significantly less than that among other groups of similar education and income. I do not apologize for considering that a good thing.

A close friend of mine is a very distinguished scientist. He is also one of the few scientists I know who has lived what we used to call a Bohemian life. When we were both younger, he thought he would undertake historical research to see how many great scientists had been as fond of women as he was. I think he would have felt mildly supported if he could have found a precedent. I remember his reporting to me that his researches hadn't had any luck. The really great scientists seemed to vary from a few neutral characters to a large number who were depressingly "normal." The only gleam of comfort was to be found in the life of Jerome Cardan; and Cardan wasn't anything like enough to outweigh all the others.

So scientists are not much different from other men. They are certainly no worse than other men. But they do differ from other men in one thing. That is the point I started with. Whether they like it or not, what they do is of critical importance for the human race. Intellectually, it has transformed the climate of our time. Socially, it will decide whether we live or die, and how we live or die. It holds decisive powers for good and evil. *That* is the situation in which the scientists find themselves. They may not have asked for it, or may only have asked for it in part, but they cannot escape it. They think, many of the more sensitive of them, that they don't deserve to have this weight of responsibility heaved upon them. All they want to do is to get on with their work. I sympathize. But the scientists can't escape the responsibility—any more than they, or the rest of us, can escape the gravity of the moment in which we stand.

Doctrine of Ethical Neutrality

There is of course one way to contract out. It has been a favorite way for intellectual persons caught in the midst of water too rough for them.

It consists of the invention of categories—or, if you like, of the division of moral labor. That is, the scientists who want to contract out say, *we* produce the tools. *We* stop there. It is for *you*—the rest of the world, the politicians—to say how the tools are used. The tools may be used for purposes which most of us would regard as bad. If so, we are sorry. But as scientists, that is no concern of ours.

This is the doctrine of the ethical neutrality of science. I can't accept it for an instant. I don't believe any scientist of serious feeling can accept it. It is hard, some think, to find the precise statements which will prove it wrong. Yet we nearly all feel intuitively that the invention of comfortable categories is a moral trap. It is one of the easier methods of letting the conscience rust. It is exactly what the early 19th century economists, such as Ricardo, did in the face of the facts of the first industrial revolution. We wonder now how men, intelligent men, can have been so morally blind. We realize how the exposure of that moral blindness gave Marxism its apocalyptic force. We are now, in the middle of the scientific or second industrial revolution, in something like the same position as Ricardo. Are we going to let our consciences rust? Can we ignore that intimation we nearly all have, that scientists have a unique responsibility? Can we believe it, that science is morally neutral?

To me—it would be dishonest to pretend otherwise—there is only one answer to those questions. Yet I have been brought up in the presence of the same intellectual categories as most western scientists. It would also be dishonest to pretend that I find it easy to construct a rationale which expresses what I now believe. The best I can hope for is to fire a few sighting shots. Perhaps someone who sees more clearly than I can will come along and make a real job of it.

The Beauty of Science

Let me begin with a remark which seems some way off the point. Anyone who has ever worked in any science knows how much esthetic joy he has obtained. That is, in the actual *activity* of science, in the process of making a discovery, however humble it is, one can't help feeling an awareness of beauty. The subjective experience, the esthetic satisfaction, seems exactly the same as the satisfaction one gets from writing a poem or a novel, or composing a piece of music. I don't think anyone has succeeded in distinguishing between them. The literature of scientific discovery is full of this esthetic joy. The very best communication of it that I know comes in G. H. Hardy's book, *A Mathematician's Apology*. Graham Greene once said he thought that, along with Henry James's prefaces, this was the best account of the artistic experience ever written. But one meets the

same thing throughout the history of science. Bolyai's great yell of triumph when he saw he could construct a self-consistent, non-Euclidean geometry; Rutherford's revelation to his colleagues that he knew what the atom was like; Darwin's slow, patient, timorous certainty that at last he had got there—all these are voices, different voices, of esthetic ecstasy.

That is not the end of it. The *result* of the activity of science, the actual finished piece of scientific work, has an esthetic value in itself. The judgments passed on it by other scientists will more often than not be expressed in esthetic terms: "That's beautiful!" or "That really is very pretty!" (as the understating English tend to say). The esthetics of scientific constructs, like the esthetics of works of art, are variegated. We think some of the great syntheses, like Newton's, beautiful because of their classical simplicity, but we see a different kind of beauty in the relativistic extension of the wave equation or the interpretation of the structure of deoxyribonucleic acid, perhaps because of the touch of unexpectedness. Scientists know their kinds of beauty when they see them. They are suspicious, and scientific history shows they have always been right to have been so, when a subject is in an "ugly" state. For example, most physicists feel in their bones that the present bizarre assembly of nuclear particles, as grotesque as a stamp collection, can't possibly be, in the long run, the last word.

We should not restrict the esthetic values to what we call "pure" science. Applied science has its beauties, which are, in my view, identical in nature. The magnetron has been a marvelously useful device, but it was a beautiful device, not exactly apart from its utility but because it did, with such supreme economy, precisely what it was designed to do. Right down in the field of development, the esthetic experience is as real to engineers. When they forget it, when they begin to design heavy-power equipment about twice as heavy as it needs to be, engineers are the first to know that they are lacking virtue.

There is no doubt, then, about the esthetic content of science, both in the activity and the result. But esthetics has no connection with morals, say the categorizers. I don't want to waste time on peripheral issues—but are you quite sure of that? Or is it possible that these categories are inventions to make us evade the human and social conditions in which we now exist? But let us move straight on to something else, which is right in the grain of the activity of science and which is at the same time quintessentially moral. I mean, the desire to find the truth.

The Search for Truth

By *truth,* I don't intend anything complicated, once again. I am using the word as a scientist uses it. We all know that the philosophical examination of the concept of empirical truth gets us into some curious complexities, but most scientists really don't care. They know that the truth, as they use the word and as the rest of us use it in the language of common speech, is what makes science work. That is good enough for them. On it rests the whole great edifice of modern science. They have a sneaking sympathy for Rutherford, who, when asked to examine the philosophical bases of science, was inclined to reply, as he did to the metaphysician Samuel Alexander: "Well, what have you been talking all your life, Alexander? Just hot air! Nothing but hot air!"

Anyway, truth in their own straightforward sense is what the scientists are trying to find. They want to find what is *there.* Without that desire, there is no science. It is the driving force of the whole activity. It compels the scientist to have an overriding respect for truth, every stretch of the way. That is, if you're going to find what is *there*, you mustn't deceive yourself or anyone else. You mustn't lie to yourself. At the crudest level, you mustn't fake your experiments.

Curiously enough, scientists do try to behave like that. A short time ago, I wrote a novel in which the story hinged on a case of scientific fraud. But I made one of my characters, who was himself a very good scientist, say that, considering the opportunities and temptations, it is astonishing how few such cases there are. We have all heard of perhaps half a dozen open and notorious ones, which are on the record for anyone to read—ranging from the "discovery" of the L radiation to the singular episode of the Piltdown man.

We have all, if we have lived any time in the scientific world, heard private talk of something like another dozen cases which for various reasons are not yet public property. In some cases, we know the motives for the cheating—sometimes, but not always, sheer personal advantage, such as getting money or a job. But not always. A special kind of vanity has led more than one man into scientific faking. At a lower level of research, there are presumably some more cases. There must have been occasional Ph.D. students who scraped by with the help of a bit of fraud.

But the total number of all these men is vanishingly small by the side of the total number of scientists. Incidentally, the effect on science of such frauds is also vanishingly small. Science is a self-correcting system. That is, no fraud (or honest mistake) is going to stay undetected for long. There is no need for an extrinsic scientific criticism, because criticism is inherent in the process itself. So that all that a fraud can do is waste the time of the scientists who have to clear it up.

The remarkable thing is not the handful of scientists who deviate from the search for truth but the overwhelming numbers who keep to it. That is a demonstration, absolutely clear for anyone to see, of moral behavior on a very large scale.

We take it for granted. Yet it is very important. It differentiates science in its widest sense (which includes scholarship) from all other intellectual activities. There is a built-in moral component right in the core of the scientific activity itself. The desire to find the truth is itself a moral impulse, or at least contains a moral impulse. The way in which a scientist tries to find the truth imposes on him a constant moral discipline. We say a scientific conclusion—such as the contradiction of parity by Lee and Yang—is "true" in the limited sense of scientific truth, just as we say that it is "beautiful" according to the criteria of scientific esthetics. We also know that to reach this conclusion took a set of actions which would have been useless without the moral nature. That is, all through the marvelous experiments of Wu and her colleagues, there was the constant moral exercise of seeking and telling the truth. To scientists, who are brought up in this climate, this seems as natural as breathing. Yet it is a wonderful thing. Even if the scientific activity contained only this one moral component, that alone would be enough to let us say that it was morally un-neutral.

But is this the only moral component? All scientists would agree about the beauty and the truth. In the western world, they wouldn't agree on much more. Some will feel with me in what I am going to say. Some will not. That

doesn't affect me much, except that I am worried by the growth of an attitude I think very dangerous, a kind of technological conformity disguised as cynicism. I shall say a little more about that later. As for disagreement, G. H. Hardy used to comment that a serious man ought not to waste his time stating a majority opinion—there are plenty of others to do that. That was the voice of classical scientific nonconformity. I wish that we heard it more often.

Science in the Twenties

Let me cite some grounds for hope. Any of us who were working in science before 1933 can remember what the atmosphere was like. It is a terrible bore when aging men in their fifties speak about the charms of their youth. Yet I am going to irritate you—just as Talleyrand irritated his juniors—by saying that unless one was on the scene before 1933, one hasn't known the sweetness of the scientific life. The scientific world of the twenties was as near to being a full-fledged international community as we are likely to get. Don't think I'm saying that the men involved were superhuman or free from the ordinary frailties. That wouldn't come well from me, who have spent a fraction of my writing life pointing out that scientists are, first and foremost, men. But the atmosphere of the twenties in science was filled with an air of benevolence and magnanimity which transcended the people who lived in it.

Anyone who ever spent a week in Cambridge or Göttingen or Copenhagen felt it all round him. Rutherford had very human faults, but he was a great man with abounding human generosity. For him the world of science was a world that lived on a plane above the nation-state, and lived there with joy. That was at least as true of those two other great men, Niels Bohr and Franck, and some of that spirit rubbed off on to the pupils round them. The same was true of the Roman school of physics.

The personal links within this international world were very close. It is worth remembering that Peter Kapitza, who was a loyal Soviet citizen, honored my country by working in Rutherford's laboratory for many years. He became a fellow of the Royal Society, a fellow of Trinity College, Cambridge, and the founder and kingpin of the best physics club Cambridge has known. He never gave up his Soviet citizenship and is now director of the Institute of Physical Problems in Moscow. Through him a generation of English scientists came to have personal knowledge of their Russian colleagues. These exchanges were then, and have remained, more valuable than all the diplomatic exchanges ever invented.

The Kapitza phenomenon couldn't take place now. I hope to live to see the day when a young Kapitza can once more work for 16 years in Berkeley or Cambridge and then go back to an eminent place in his own country. When that can happen, we are all right. But after the idyllic years of world science, we passed into a tempest of history, and, by an unfortunate coincidence, we passed into a technological tempest too.

The discovery of atomic fission broke up the world of international physics. "This has killed a beautiful subject," said Mark Oliphant, the father figure of Australian physics, in 1945, after the bombs had dropped. In intellectual terms, he has not turned out to be right. In spiritual and moral terms, I sometimes think he has.

A good deal of the international community of science remains in other fields—in great areas of biology, for example. Many biologists are feeling the identical liberation, the identical joy at taking part in a magnanimous enterprise, that physicists felt in the twenties. It is more than likely that the moral and intellectual leadership of science will pass to biologists, and it is among them that we shall find the Rutherfords, Bohrs, and Francks of the next generation.

The Physicist, a Military Resource

Physicists have had a bitterer task. With the discovery of fission, and with some technical breakthroughs in electronics, physicists became, almost overnight, the most important military resource a nation-state could call on. A large number of physicists became soldiers not in uniform. So they have remained, in the advanced societies, ever since.

It is very difficult to see what else they could have done. All this began in the Hitler war. Most scientists thought then that Nazism was as near absolute evil as a human society can manage. I myself thought so. I still think so, without qualification. That being so, Nazism had to be fought, and since the Nazis might make fission bombs—which we thought possible until 1944, and which was a continual nightmare if one was remotely in the know—well, then, we had to make them too. Unless one was an unlimited pacifist, there was nothing else to do. And unlimited pacificism is a position which most of us cannot sustain.

Therefore I respect, and to a large extent share, the moral attitudes of those scientists who devoted themselves to making the bomb. But the trouble is, when you get onto any kind of moral escalator, to know whether you're ever going to be able to get off. When scientists became soldiers they gave up something, so imperceptibly that they didn't realize it, of the full scientific life. Not intellectually. I see no evidence that scientific work on weapons of maximum destruction has been in any intellectual respect different from other scientific work. But there is a moral difference.

It may be—scientists who are better men than I am often take this attitude, and I have tried to represent it faithfully in one of my books—that this is a moral price which, in certain circumstances, has to be paid. Nevertheless, it is no good pretending that there is not a moral price. Soldiers have to obey. That is the foundation of their morality. It is not the foundation of the scientific morality. Scientists have to question and if necessary to rebel. I don't want to be misunderstood. I am no anarchist. I am not suggesting that loyalty is not a prime virtue. I am not saying that all rebellion is good. But I am saying that loyalty can easily turn into conformity, and that conformity can often be a cloak for the timid and self-seeking. So can obedience, carried to the limit. When you think of the long and gloomy history of man, you will find that far more, and far more hideous, crimes have been committed in the name of obedience than have ever been committed in the name of rebellion. If you doubt that, read William Shirer's *Rise and Fall of the Third Reich*. The German officer corps were brought up in the most rigorous code of obedience. To them, no more honorable and God-fearing body of men could conceivably exist. Yet in the name of obedience, they were party to, and assisted in, the most wicked large-scale actions in the history of the world.

Scientists must not go that way. Yet the duty to question is not much of a support when you are living in the middle of an organized society. I speak with feeling here. I was an official for 20 years. I went into official life at the beginning of the war, for the reasons that prompted my scientific friends to begin to make weapons. I stayed in that life until a year ago, for the same reason that made my scientific friends turn

into civilian soldiers. The official's life in England is not quite so disciplined as a soldier's, but it is very nearly so. I think I know the virtues, which are very great, of the men who live that disciplined life. I also know what for me was the moral trap. I, too, had got onto an escalator. I can put the result in a sentence: I was coming to hide behind the institution; I was losing the power to say no.

A Spur to Moral Action

Only a very bold man, when he is a member of an organized society, can keep the power to say no. I tell you that, not being a very bold man, or one who finds it congenial to stand alone, away from his colleagues. We can't expect many scientists to do it. Is there any tougher ground for them to stand on? I suggest to you that there is. I believe that there is a spring of moral action in the scientific activity which is at least as strong as the search for truth. The name of this spring is *knowledge*. Scientists *know* certain things in a fashion more immediate and more certain than those who don't comprehend what science is. Unless we are abnormally weak or abnormally wicked men, this knowledge is bound to shape our actions. Most of us are timid, but to an extent, knowledge gives us guts. Perhaps it can give us guts strong enough for the jobs in hand.

I had better take the most obvious example. All physical scientists *know* that it is relatively easy to make plutonium. We know this, not as a journalistic fact at second hand, but as a fact in our own experience. We can work out the number of scientific and engineering personnel needed for a nation-state to equip itself with fission and fusion bombs. We *know* that, for a dozen or more states, it will only take perhaps six years, perhaps less. Even the best informed of us always exaggerate these periods.

This we know, with the certainty of —what shall I call it?—engineering truth. We also—most of us—are familiar with statistics and the nature of odds. We know, with the certainty of statistical truth, that if enough of these weapons are made, by enough different states, some of them are going to blow up, through accident, or folly, or madness—the motives don't matter. What does matter is the nature of the statistical fact.

All this we *know*. We know it in a more direct sense than any politician because it comes from our direct experience. It is part of our minds. Are we going to let it happen?

All this we *know*. It throws upon scientists a direct and personal responsibility. It is not enough to say that scientists have a responsibility as citizens. They have a much greater one than that, and one different in kind. For scientists have a moral imperative to say what they know. It is going to make them unpopular in their own nation-states. It may do worse than make them unpopular. That doesn't matter. Or at least, it does matter to you and me, but it must not count in the face of the risks.

Alternatives

For we genuinely know the risks. We are faced with an either-or, and we haven't much time. The *either* is acceptance of a restriction of nuclear armaments. This is going to begin, just as a token, with an agreement on the stopping of nuclear tests. The United States is not going to get the 99.9-percent "security" that it has been asking for. This is unobtainable, though there are other bargains that the United States could probably secure. I am not going to conceal from you that this course involves certain risks. They are quite obvious, and no honest man is going to blink them. That is the *either*. The *or* is not a risk but a certainty. It is this. There is no agreement on tests. The nuclear arms race between the United States and the U.S.S.R. not only continues but accelerates. Other countries join in. Within, at the most, six years, China and several other states have a stock of nuclear bombs. Within, at the most, ten years, some of those bombs are going off. I am saying this as responsibly as I can. *That* is the certainty. On the one side, therefore, we have a finite risk. On the other side we have a certainty of disaster. Between a risk and a certainty, a sane man does not hesitate.

It is the plain duty of scientists to explain this either-or. It is a duty which seems to me to come from the moral nature of the scientific activity itself.

The same duty, though in a much more pleasant form, arises with respect to the benevolent powers of science. For scientists know, and again with the certainty of scientific knowledge, that we possess every scientific fact we need to transform the physical life of half the world. And transform it within the span of people now living. I mean, we have all the resources to help half the world live as long as we do and eat enough. All that is missing is the will. We *know* that. Just as we know that you in the United States, and to a slightly lesser extent we in the United Kingdom, have been almost unimaginably lucky. We are sitting like people in a smart and cozy restaurant and we are eating comfortably, looking out of the window into the streets. Down on the pavement are people who are looking up at us, people who by chance have different colored skins from ours, and are rather hungry. Do you wonder that they don't like us all that much? Do you wonder that we sometimes feel ashamed of ourselves, as we look out through that plate glass?

Well, it is within our power to get started on that problem. We are morally impelled to. We all know that, if the human species does solve that one, there will be consequences which are themselves problems. For instance, the population of the world will become embarrassingly large. But that is another challenge. There are going to be challenges to our intelligence and to our moral nature as long as man remains man. After all, a challenge is not, as the word is coming to be used, an excuse for slinking off and doing nothing. A challenge is something to be picked up.

For all these reasons, I believe the world community of scientists has a final responsibility upon it—a greater responsibility than is pressing on any other body of men. I do not pretend to know how they will bear this responsibility. These may be famous last words, but I have an inextinguishable hope. For, as I have said, there is no doubt that the scientific activity is both beautiful and truthful. I cannot prove it, but I believe that, simply because scientists cannot escape their own knowledge, they also won't be able to avoid showing themselves disposed to good.

Comments by Theodore M. Hesburgh, C.S.C.

Sir Charles has wonderfully spoken to us as an ex-scientist. At the risk of coining an ambiguous word, I speak to you as a pro-scientist. I began intellectually hoping to be a philosopher. Then, I spent six years in the graduate study of theology, which I subsequently taught. I have this in common with Sir Charles, that shortly thereafter it appeared that a lifetime devoted to my first love was not to be, and I became an administrator. This led me into association with scientists.

Since then, I have spent almost seven years on the National Science Board, five years with high-energy physicists on the Midwestern Universities Research Association, five years concerned with atoms-for-peace in the General Conference of the International Atomic Energy Agency in Vienna, five years with the Nutrition Foundation, three years with the Physical Science Study Committee, and three years with all sorts of scientists on the Policy Advisory Board of the Argonne National Laboratory. While we all resent guilt by association, I trust that members of this association will turn the coin and accept the fact that I favor science and am, therefore, a pro-scientist.

Sir Charles has spoken frankly. I want to be equally frank. Much of what he has said I accept gladly and acclaim. Some other opinions of his I question. In the area of agreement, I am probably wasting my time by stating a majority opinion, but at least it gets us off to a good start.

I agree with full heart that the present-day scientist cannot be morally neutral. Neither can the man of any other profession, because neutrality is an illusion. The most fundamental ethical fact is that we are responsible for our actions and, to some extent, for the consequences of our actions. In the complexity of modern society, moral responsibility does, of course, become correspondingly complex, and there certainly is the tendency, which Sir Charles notes, to contract out that which one may not legitimately pass into another's hands and be completely done with. I believe that Robert Oppenheimer had something of this thought when he remarked after Nagasaki and Hiroshima that at last the scientist has known sin.

Science as a Power for Good

One need not, however, be exclusively concerned with the evil that is done through the instrumentality of science. Sir Charles has lightly touched upon science as a means of great good in the social order. Personally, I believe that here is an area where the scientist can atone for sin. No human being relishes the thought that other human beings are miserable, sick or hungry, homeless or without hope, when modern science has it within its grasp to bring relief. I am always slightly sickened at the thought that we spend more in this country for one atomic submarine than for the totality of agricultural research. We know that half of the food crop of hungry nations is destroyed by rot, sprouting, and bacteria, and we know that radiation can preserve these essential foods, and yet we have not devised a workable program to double the food supply of the hungry. We know that malaria can be exterminated. We know how to do this effectively, but we have not pressed for a program to do it, although people continue to die unnecessarily of malaria. We know that desalinization of sea or brackish water is essential to food production in some hungry nations, we know something of what chemical fertilizers can do, and yet we have not used our knowledge to press home the performance. We are geniuses at organization, and yet, though the world food production has grown faster than the world population, we have not clamored for effective means to get the food where the hunger is.

I believe that science today has the magnificent power of creating conditions that will allow man, for the first time in recorded history, to master the created universe in such a way that human dignity can rise above the miserable conditions that reduce man to little better than an animal. Will we use this power to help our fellow man, or will we use it to multiply our own luxuries? This is the question that perplexes me when I think of the personal moral responsibility of scientists.

Science is by its nature neutral. It can be used for good or evil. It is man, the scientist, who directs its use. I agree that the scientist is totally and rather universally committed to truth, that he does not falsify evidence, but I think we should not, from this fact alone, pass out halos to a profession of persons doing that which is essential to success and status in their profession. To say that a man does not do that which, if done, would ruin him is not cause for the highest paean of praise, although this line of reasoning is comparable to that which is theologically employed when fear of hell gets more emphasis in religion than love of God and our fellow men.

Ethical Problems of All Men

As you may have suspected, I am edging toward an area of disagreement with Sir Charles. Scientists do well in their commitment to truth and beauty; without this commitment we would not find so many admirable and decently human people among the scientists. But there are generally admitted to be four transcendentals, discrete yet clearly identified. Truth and beauty are two of them, being and the good are the others. *Being* gets us into metaphysics, which I personally find slightly more complicated than physics (maybe that is why they call it the science beyond physics). The sciences traditionally dealing with the good are ethics and moral theology. Scientists may ignore them or deny them if they wish, for ethics and moral theology employ different methods in getting at truth and view it in a broader context than that of "what makes science work," but I submit that the ignoring of ethics and moral theology is ignorance of a more serious nature than that which attends inadequate science. Plato and Aristotle, and their Christian counterparts, Augustine and Aquinas, had some deep and relevant reflections upon the nature of what is good and what is man's good, and of what the philosophical and theological means of determining these are. I quite agree that alongside of these giants of the human intellect at work, much of what is termed philosophy today is indeed, in the words of Rutherford, "hot air," but what they had to say about the ethical problems of all men of all times is air of greatest purity. Any scientist may read and dismiss them as irrelevant, but he may not dismiss them without reading them, for this is in a sense the mortal sin of science—not looking at all the evidence at hand.

Crucial Problem of Our Age

One last word about the most crucial problem of our age: survival. I am not convinced that the "either-or" is completely responsive to the situation that confronts us. I agree with Sir Charles that naive pacifism is out. Read Constantine Fitzgibbon's *When the Kissing Had To Stop* if you still have any doubts.

On the other hand, getting back to Sir Charles's "either-or," allow me to distrust statistical certainty where men are involved. One might make a good case for the statistical certainty of the use of gas in the last war: the side that was losing had it; it had been used before; they were desperate. As to the risk, suppose we sacrifice realistic demands for adequate inspection and control and disarm. Suppose the opposition cheats and the final result is world domination by the Soviets. I submit that in this eventuality we have a world in which you and I live, but really have nothing to live for.

Returning to an earlier page of Sir Charles, I would like to underline that science is one of those areas in which

men, in a very troubled world, may collaborate despite widely separated philosophical differences. Possibly the commitment to scientific truth and beauty is strong enough in this world to bridge the gap and establish a brotherhood impossible along ideological lines. I have seen this happen in my atoms-for-peace work. Here is a special strength of science: that men who love her dearly find a world in which mutual respect and friendship are strengthened in the pursuit of a common goal. Let us hope that the pursuit of truth, and the love of beauty, lead all the scientists of all the world toward that goal that we all seek—the good that science makes possible to human beings who live in hope of a better world than that which we now inhabit.

Comments by William O. Baker

I am honored to respond, on behalf of the community of scientists, to the compelling issues drawn up so deftly in Sir Charles's address.

I should say, first, that few, if any, scientists in the free world would be against his contentions about moral values and responsibilities. Therefore, I can most gainfully remark on a rather practical aspect of the matter, as becomes an industrialist—that is, the old query of what to do and how to do it, concerning public morality, since the matter of doing it or not is so convincingly treated by Sir Charles.

Thus, how can the scientists best labor in the macrocosmos of the world outside their laboratories and libraries? This is what I shall try to answer.

First, above all, they must gain public trust and understanding, even though, because of its inner qualities, political and social judgments derived from science may be less perfect than expected. Second, scientists must carry forth to all the world the bright hope, the good fortune, that science does betoken for mankind. We can indeed negate the spreading cynicism and nihilism of our time. Both are alien to science and to research. Science gainsays the words of a present-day anthropologist: "America is the only culture which has passed from barbarism to decline without going through a stage of civilization."

Science and its fruits do indeed confer that joy and sense of beauty—the esthetic content, as Sir Charles says—that can give our times social strength and buoyancy and *liveliness*. A society caught up in the great adventure of an Echo satellite, a reconstructed biological gene, a niobium-tin compound superconductor operating far above absolute zero—this will not lapse into Huxley's "Brave New World." Free people of today are ready to take up Wordsworth's offer:

> Come forth into the light of things,
> Let Nature be your teacher.
> She has a world of ready wealth,
> Our minds and hearts to bless—
> Spontaneous wisdom breathed by health,
> Truth breathed by cheerfulness.

So, over all, scientists must learn to *express* just those human virtues which Sir Charles said so kindly in his opening words were theirs.

Public Faith and Following

But now we have to go back to the first urgency for scientists—public faith and public following. The simple fact now is that scientists do not have the trust of people and of nations in dealing with the issues that Sir Charles raises—the issues of peace and war, of feast and famine, of life and death in their temporal forms. This is not a complaint; it is a realization. I could support this assertion by many grievous examples. Following Sir Charles's theme, I shall, however, refer to only two. The first is the action that followed the scientific communities' plea of 1945–46 to achieve immediately nuclear disarmament and agreement on nuclear weapons between all nations of the world. Some statesmen in our own government indeed cared deeply about this issue. Some scientists worked hard with them to awaken the world and its politics to the nuclear terror shortly to come. These scientists enlisted others in an effort to see whether what looked to many like a monopoly of nuclear weapons would soon be a world-wide nuclear arms race.

I happened to be one of a task force that was gathered officially, with State Department sanction, at the very beginning of 1946 to prepare a detailed scientific estimate of just what Sir Charles now speaks of as an "engineering truth." We found, of course, the engineering truth that another country, explicitly the Soviet Union, would have nuclear weapons in a certain number of years after 1946—a number which we carefully estimated. Our estimate, which is a matter of record, was off by little more than a year, and it was, indeed, too conservative an estimate. But it was by no means trusted, and—an equally sorry circumstance—we lacked the skill to make people believe and heed it.

A somewhat similar but rather more complex situation besets us now in regard to the nuclear test ban. You remember that, following the technical agreement of the summer of 1958 for a test detection network, scientists working on the subject were obliged drastically to revise their estimate of the known efficiency of detection of nuclear events. This necessity and subsequent studies of the subject have aroused a widespread mistrust among national leaders, and perhaps among the populace at large, concerning the reliability of scientific judgments and decisions.

Limitations of Scientific Certainty

So I would like, in the space available for comment, to say something about the inner nature of science and technology and of scientists and engineers—something which must be understood by all the world if we are to operate practically in the condition of moral unneutrality that has been invoked. These inner qualities really turn out to be special limits on science and technology. To state it baldly, scientifically there are limits on truth, there are limits on certainty, and there are limits on discovery itself. Maybe the limit on certainty is the most important to explore here. Scientific findings, scientific facts, are usually thought of as symbols of certainty. But people must realize that these findings are certain only with respect to a particular frame of reference. That frame of reference is, broadly, the present state of knowledge or the present position of scientific thought. Richard Feynman put this eloquently in a lecture on the value of science, delivered in 1955. He said, "We have found it of paramount importance that in order to progress we must recognize the ignorance and leave room for doubt. Scientific knowledge is a body of statements of varying degrees of certainty—some most unsure, some nearly sure, none *absolutely* certain . . . . Now we scientists are used to this, and we take it for granted that it is perfectly consistent to be unsure—that it is possible to live and *not* know." And so the world, facing the possibility of an era blessed by the fruits of science, as Sir Charles points out, must learn to accept the uncertainties of science.

Correspondingly, the truth is also subject to drastic revision in the light of discovery. Note carefully the difference between this kind of revision of "truth" and that in which the truth is compared to falsehood, deceit, or clumsy human error. Indeed, since wave mechanics has

supplemented classical mechanics in the description of material events, the scientists' own concepts of truth and certainty have dramatically changed. But much of the *popular* view of science is still related to the deterministic description of the state of a physical system. Technically, this reached its climax in Newton's revelation of the basis of Kepler's laws governing the motion of the heavenly bodies. However, in atomic physics this causal deterministic account has been vigorously displaced by the quantum theory, involving a universal quantum of action. Thus, for nearly 60 years the physicist, and later the chemist, have had to make experimental conditions such that they could describe universally their findings without being dependent upon a particular quantum which was being observed at that particular time. In other words, to make these experiments anything like a truthful description, we have had to work with such heavy-handed measurements that the individual quanta of action were completely disregarded. However, in doing this we threw away the old-time goal of certainty of position in time or in space, and thus a certainty of movement too.

Hence, in a quite technical way, but with an abiding philosophical meaning, the scientists of our age and also the engineers who work with nuclear physics and with the tools of solid-state electronics, like transistors and magnets, have already come to terms with the kind of uncertainty and incomplete truth with which they must live. But, along with this, of course, there is a quantization of truth. Never can the scientist deal with a half truth, even though it may resemble that fragment of Irish confetti called a "half brick" in that both are said sometimes to carry further than the whole. The scientist has to tell the whole truth as he knows it in that moment in time, and nothing less or different can be expected. The situation relative to detection of underground nuclear explosions vividly illustrates this.

Science and Compromise

This brings us to some other large limitations in the tactics of science with respect to their harmonious integration in human affairs. For instance, that esteemed virtue of some of the noblest leaders of societies and of nations, the ability to compromise, is painfully, utterly lacking in the scientist producing new science. My late colleague Karl Jansky had powerful reasons for regarding the sibilant murmurs of his radio research antennas as some earthborn interference. This would have been just the sensible thing to decide on and allow for in the decisions on power and frequency then shaping up for long-distance radio usage. But the refusal of any researcher to compromise the possibilities led Jansky to the discovery of radio astronomy through radiation from the stars. Likewise, we cannot say that we will make an international agreement defining the correct amino acid sequence in the helix of a protein-nucleic acid molecule, convenient as that might be. In contrast, of course, we do make just such agreements about the gold value of the dollar, about international law, even about the time of day. Is it not well that science warns that all cannot be compromised? George Orwell, in *1984*, warns grimly about such deep danger to human freedom: "For it is only by reconciling contradictions that power can be retained infinitely."

Discovery and Individuality

Finally, concerning the limitations on discovery, here we must respond to the popular queries, Why don't the scientists do the things we need to have done —why isn't there a cure for cancer now, why don't we have a defense against nuclear weapons, why cannot we make more reliable moon rockets, why don't we understand the forecasting of weather? Thus, on and on, the infinity of unanswered questions flows, and as long as the human race advances, so will it ever flow. The point is that the scientist does not really know how to multiply—or perhaps one might better say to distribute—his efforts. It is not useful for a team of 100 scientists each to have one one-hundredth of a good idea. No one ever synthesized an important new idea in science that way. The ideas of scientific discovery come one at a time from one person and one mind at a time. Sometimes two or three can aid each other. But scientific discovery cannot be collectivized, and it does not flourish in collectivized structures. As Sir Charles has said, individuality, independence, scientific nonconformity are the requisites for discovery.

Even then, how hard and slow it is. Take the case of light—the mystery and adornment of the universe since the Creation: "Let there be light!" Thousands of scientists have studied it, in tens of thousands of ways. But only this year was the concept of coherent light —light whose waves start and go from a source in unison—realized in the optical maser. Thus, Schawlow and Townes envisioned, and there has been achieved, light never before beheld. This is past the halfway point of the 20th century —what else, indeed, have scientists not beheld? All these things too, I hope, the people will understand and will have sympathy for, when science has the operational role for which Sir Charles Snow petitions.

Altogether, then, I ask that scientists be trusted mightily in view of the changes, the revisions, the alterations that they will constantly have to make in their role in large human affairs. In the small, they do almost universally trust each other, as Sir Charles has brought out so eloquently in his novels, even by dramatizing the rare cases of mistrust. The experiences of many decades now have shown that this trust is merited and does good. When the trust has been sufficiently enlarged, neutral scientific moralisms will diminish and disappear. And the natural scientist will once more call on the poet (Wordsworth) to say that, in the end, science belongs to all, not part, of man:

> . . . For I have learned
> To look on nature, not as in the hour
> Of thoughtless youth; but hearing oftentimes
> The still, sad music of humanity,
> Nor harsh nor grating, though of ample power
> To chasten and subdue. And I have felt
> A presence that disturbs me with the joy
> Of elevated thoughts; a sense sublime,
> Of something far more deeply interfused,
> Whose dwelling is the light of setting suns,
> And the round ocean and the living air,
> And the blue sky, and in the mind of man. . . ."